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Transmission Line Construction and Maintenance

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The information herein was derived from personal observation and participation in the construction of overhead transmission lines for over 40 years. Detailed information, specific tools and equipment have been provided previously and are available in IEEE Standard 524-2003 and IEEE Standard 524A-1993.

The purpose of this chapter is to give a general overview of the steps that are necessary in the planning and construction of a typical overhead transmission line, to give newcomers to the trade a general format to follow, and assist transmission design engineers in understanding how such lines are built.

Stringing overhead conductors in transmission is a very specialized type of construction requiring years of experience, as well as equipment and tools that have been designed, tried, and proven to do the work. Because transmission of electrical current is normally at higher voltages (69 kV and above), conductors must be larger in diameter and span lengths must be longer than in normal distribution. Although proximity to other energized lines may be limited on the right-of-way, extra care must be exercised to protect the conductor so that when energized, power loss and corona are not a problem.

There are four methods that can be used to install overhead transmission conductors:

1. Slack stringing
2. Semi-tension stringing
3. Full-tension stringing
4. Helicopter stringing

Slack stringing can only be utilized if it is not necessary to keep the conductor off of the ground, and if no energized lines lie beneath the line being strung. In this method the pulling lines are pulled out on the ground, threaded through the stringing blocks, and the conductor is pulled in with less tension than is required to keep it off the ground. This is not considered to be an acceptable method when demands involve maximum utilization of transmission requirements.

Semi-tension methods are merely an upgrading of slack stringing, but do not necessarily keep the conductor completely clear of the ground, or the lines used to pull.

Full-tension stringing is a method of installing the conductors and overhead groundwire in which sufficient pulling capabilities on one end and tension capabilities on the other, keep the wires clear of any obstacles during the movement of the conductor from the reel to its final sag position. This ensures that

these current-carrying cables are “clipped” into the support clamps in the best possible condition, which is the ultimate goal of the work itself.

Stringing with helicopters, which is much more expensive per hour of work, can be much less expensive when extremely arduous terrain exists along the right-of-way and when proper pre-planning is utilized. Although pulling conductors themselves with a helicopter can be done, it is limited and normally not practical. Maximum efficiency can be achieved when structures are set and pilot lines are pulled with the helicopter, and then the conductor stringing is done in a conventional manner. Special tools (such as stringing blocks) are needed if helicopters are used.

So that maximum protection of the conductor is realized and maximum safety of personnel is attained, properly designed and constructed tools and equipment are tantamount to a successful job. Because the initial cost of these tools and equipment represent such a small percentage of the overall cost of the project, the highest quality should be used, thus minimizing “down time” and possible failure during the course of construction.

11.1 Tools

Basic tools needed to construct overhead transmission lines are as follows:

1. Conductor blocks
2. Overhead groundwire blocks
3. Catch-off blocks
4. Sagging blocks
5. Pulling lines
6. Pulling grips
7. Catch-off grips
8. Swivels
9. Running boards
10. Conductor lifting hooks
11. Hold-down blocks

Conductor blocks are made in the following configurations:

1. Single conductor
2. Multiple conductor
3. Multiversal type (can be converted from bundle to single, and vice versa)
4. Helicopter

Conductor blocks should be large enough to properly accommodate the conductor and be lined with a resilient liner such as neoprene or polyurethane and constructed of lightweight, high-strength materials. Some sheaves are made of synthetic material such as nylatron. Sheaves should be mounted on anti-friction ball bearings to reduce the tension required in stringing and facilitate proper sagging. Conductor blocks are available for stringing single conductors or multiple conductors. Some are convertible, thus enhancing their versatility. When stringing multiple conductors, it is desirable to pull all conductors with a single pulling line so that all conductors in the bundle have identical tension history. The running board makes this possible. Pulling lines are divided into two categories:

1. Steel cable
2. Synthetic rope

Because of the extra high tension required in transmission line construction, steel pulling lines and pilot lines are most practical to use. Torque-resistant, stranded, and swagged cable are used so that ball bearing swivels can be utilized to prevent torque buildup from being transferred to the conductor. Some

braided or woven steel cables are also used. If synthetic ropes are utilized, the most important features should include:

1. No torque
2. Very minimum elongation
3. No “kinking”
4. Easily spliced
5. High strength/small diameter
6. Excellent dielectric properties

Stringing overhead groundwires does not normally require the care of current-carrying conductors. Most overhead groundwires are stranded steel construction and the use of steel wire with a fiber-optic core for communications has become a common practice. Special care should be taken to ensure that excessive bending does not occur when erecting overhead groundwires with fiber-optic centers, such as OPT-GW (Optical Power Telecommunications—Ground Wire) and ADSS (All Dielectric Self-Supporting Cable). New types of conductor such as ACCR, Aluminum Conductor Composite Reinforced, need special care. Use of array (multi-sheave in tandem) blocks may be necessary. Special instructions are available from the manufacturer, which specify minimum sheave and bullwheel diameter for construction. OPT-GW should be strung using an antirotational device to prevent the cable from twisting.

11.2 Equipment

Pullers are used to bring in the main pulling line. Multi-drum pullers, called pilot line winders, are used to tension string the heavy pulling cable.

Primary pullers are used to tension string the conductors. These pullers are either drum type or bullwheel type. The drum type is used more extensively in many areas of North America because the puller and pulling cable are stored on one piece of equipment, but it is not practical in other areas because it is too heavy. Thus, the bullwheel type is used allowing the puller and pulling cable to be separated onto two pieces of equipment. Also, the pulling cable can be separated into shorter lengths to allow easier handling, especially if manual labor is preferred.

Tensioners should be bullwheel type using multigroove wheels for more control. Although V groove machines are used on some lighter, smaller conductors, they are not recommended in transmission work because of the crushing effect on the conductor. Tensioners are either mounted on a truck or trailer.

Reel stands are used to carry the heavy reels of conductor and are equipped with brakes to hold “tailing tension” on the conductor as it is fed into the bullwheel tensioner. These stands are usually mounted on a trailer separated from the tensioner.

Helicopters are normally used to fly in a light line which can be used to pull in the heavier cable.

11.3 Procedures

Once the right-of-way has been cleared, the following are normal steps taken in construction:

1. Framing
2. Pulling
3. Pulling overhead groundwire up to sag and installation
4. Pulling in main line with pilot line
5. Stringing conductors
6. Sagging conductors
7. Clipping in conductors
8. Installing spacer or spacer dampers where applicable

Framing normally consists of erecting poles, towers, or other structures, including foundations and anchors on guyed structures. It is desirable for the stringing blocks to be installed, with finger lines, on

the ground before structures are set, to eliminate an extra climb later. Helicopters are used to set structures, especially where rough terrain exists or right-of-way clearances are restricted.

Once structures are secure, overhead groundwire and pilot lines are pulled in together with a piece of equipment such as a caterpillar or other track vehicle. A helicopter is also used to fly in these lines. Once the overhead groundwires are in place, they are sagged and secured, thus giving the structures more stability for the stringing of the conductors. This is especially important for guyed structures.

Normally the three pilot lines (typically 3/8 in. diameter swagged steel cable) pull in the heavier pulling line (typically 3/4 in. diameter or 7/8 in. diameter swagged steel) under tension. The main pulling line is then attached to the conductor which is strung under full tension. Once the conductor is “caught off,” the main pulling line is returned for pulling of the next phase.

Once the conductors are in place, they are then brought up to final sag and clipped into the conductor clamps provided. If the conductor is a part of a bundle per phase, the spacers or spacer dampers are installed, using a spacer cart which is either pulled along from the ground or self-propelled.

Coordination between design engineers and construction personnel is very important in the planning and design of transmission lines. Although it is sometimes impossible to accommodate the most efficient capabilities of the construction department (or line contractor), much time and money can be conserved if predesign meetings are held to discuss items such as the clearances needed for installing overhead groundwire blocks, hardware equipped with “work” holes to secure lifting hooks or blocks, conductor reel sizes compatible with existing reel stands, length of pull most desirable, or towers equipped to facilitate climbing.

For maximum safety of personnel constructing transmission lines, proper and effective grounding procedures should be utilized. Grounding can be accomplished by:

1. adequate grounding of conductors being strung and pulling cables being used, or
2. fully insulating equipment and operator,
3. isolating equipment and personnel.

All equipment, conductors, anchors, and structures within a defined work area must be bonded together and connected to the ground source. The recommended procedures of personnel protection are the following:

1. Establish equipotential work zones.
2. Select grounding equipment for the worst-case fault.
3. Discontinue all work when the possibility of lightning exists which may affect the work site.

In addition to the grounding system, the best safety precaution is to treat all equipment as if it could become energized.

11.4 Helicopters

As already mentioned, the use of helicopters is another option that is being chosen more frequently for transmission system construction and maintenance. There are a wide variety of projects where helicopters become involved, making the projects easier, safer, or more economical. When choosing any construction or maintenance method, identify the work to be accomplished, analyze the potential safety aspects, list the possible alternatives, and calculate the economics. Helicopters add a new dimension to this analytical process by adding to the alternatives, frequently reducing the risks of accident or injury, and potentially reducing costs. The most critical consideration in the use of a helicopter is the ability to safely position the helicopter and line worker at the work location.

11.4.1 Conductor Stringing

Helicopters are used for conductor stringing on towers through the use of pilot lines. Special stringing blocks are installed at each tower and a helicopter is brought in and attached to a pilot line. The

helicopter flies along the tower line and slips the pilot line in through each stringing block until it reaches the end of the set of towers for conductor pulling, where it disconnects and the pilot line is transferred to a ground crew. The ground crew then proceeds to pull the conductor in the conventional manner (Caulkins, 1987). The helicopter may also be used to monitor the conductor pulling and is readily available to assist if the conductor stalls at any tower location.

11.4.2 Structure and Material Setting

The most obvious use of helicopters is in the setting of new towers and structures. Helicopters are frequently used in rough terrain to fly in the actual tower to a location where a ground crew is waiting to spot the structure into a preconstructed foundation. In addition, heavy material can be transported to remote locations, as well as the construction crew.

The use of helicopters can be especially critical if the tower line is being replaced following a catastrophe or failure. Frequently, roads and even construction paths are impassable or destroyed following natural disasters. Helicopters can carry crews and materials with temporary structures that can be erected within hours to restore tower lines. Again, depending on the terrain and current conditions, whether the existing structure is repaired or temporary tower structures are utilized, the helicopter is invaluable to carry in the needed supplies and personnel.

11.4.3 Insulator Replacement

A frequent maintenance requirement on a transmission system is replacing insulators. This need is generated for various reasons, including line upgrading, gunshots, environmental damage, or defects in the original insulator manufacturing. With close coordinated crews, helicopters can maximize the efficiency of the replacement project.

Crews are located at several towers to perform the actual insulator removal and installation. The crews will do the required setup for a replacement, but the helicopter can be used to bring in the necessary tools and equipment. The crew removes the old insulator string and sets it to one side of the work location. When the crews are ready, the helicopter flies in the new insulator string to each tower. The crew on the tower detaches the new insulator string from the helicopter, positions it, and then attaches the old string to the helicopter, which removes the string to the staging area. With a well-coordinated team of helicopters and experienced line workers, it is not unusual to achieve a production rate of replacing all insulators on four three-phase structures per crew per day. Under ideal conditions, crews are able to replace the insulators on a structure in one hour (Buchholz, 1987).

11.4.4 Replacing Spacers

One of the first uses of helicopters in live-line work was the replacement of spacers in the early 1980s. This method was a historic step in live-line work since it circumvented the need for hot sticks or insulated aerial lift devices.

The first projects involved a particular spacer wearing into the conductor strands, causing the separation of the conductor. Traditionally, the transmission line would have been de-energized, grounded, and either a line worker would have utilized a spacer cart to move out on the line to replace the spacer, or the line would have been lowered and the spacer replaced and the conductor strengthened. The obvious safety dilemma was whether the conductor could support a line worker on a spacer cart or whether it was physically able to withstand the tensions of lowering it to the ground. By utilizing a helicopter and bare-hand work methods, the spacers were able to be replaced and the conductor strengthened where necessary with full-tension compression splices while providing total safety to the line workers and a continuous supply of energy over the transmission lines. One of the early projects achieved a replacement and installation of 25,000 spacers without a single accident or injury. A typical spacer replacement required about 45 sec, including the travel time between work locations (Buchholz, 1987).

11.4.5 Insulator Washing

Another common practice is to utilize helicopters for insulator washing. Again, this is a method that allows for the line to remain energized during the process. The helicopter carries a water tank that is refilled at a staging area near the work location. A hose and nozzle are attached to a structure on the helicopter and are operated by a qualified line worker who directs the water spray and adequately cleans the insulator string. Again, with the ease of access afforded by the helicopter, the speed of this operation can result in a typical three-phase tower being cleaned in a few minutes.

11.4.6 Inspections

Helicopters are invaluable for tower line and structure inspections. Due to the ease of the practice and the large number of inspections that can be accomplished, utilities have increased the amount of maintenance inspections being done, thus promoting system reliability.

Helicopters typically carry qualified line workers who utilize stabilizing binoculars to visually inspect the transmission tower for signs of rusting or weakness and the transmission hardware and conductor for damage and potential failure. Infrared inspections and photographic imaging can also be accomplished from the helicopter, either by mounting the cameras on the helicopter or through direct use by the crew. During these inspections, the helicopter provides a comfortable situation for accomplishing the necessary recording of specific information, tower locations, etc. In addition, inspections from helicopters are required following a catastrophic event or system failure. It is the only logical method of quickly inspecting a transmission system for the exact location and extent of damage.

11.4.7 Helicopter Method Considerations

The ability to safely position a helicopter and worker at the actual work site is the most critical consideration when deciding if a helicopter method can be utilized for construction or maintenance. The terrain and weather conditions are obvious factors, as well as the physical spacing needed to position the helicopter and worker in the proximity required for the work method. If live-line work methods are to be utilized, the minimum approach distance required for energized line work must be calculated very carefully for every situation. The geometry of each work structure, the geometry of the individual helicopter, and the positioning of the helicopter and worker for the specific work method must be analyzed. There are calculations that are available to analyze the approach distances (IEEE Task Force 15.07.05.05, 1999).

When choosing between construction and maintenance work methods, the safety of the line workers is the first consideration. Depending on circumstances, a helicopter method may be the safest work method. Terrain has always been a primary reason for choosing helicopters to assist with projects since the ability to drive to each work site may not be possible. However, helicopters may still be the easiest and most economic alternative when the terrain is open and flat, especially when there are many individual tower locations that will be contacted. Although helicopters may seem to be expensive on a per person basis, the ability to quickly position workers and easily move material can drastically reduce costs. When live-line methods can be utilized, the positioning of workers, material, and equipment becomes comparatively easier.

Finally, if the safe use of the helicopter allows the transmission systems to remain energized throughout the project, the helicopter may be the only possible alternative. Since the transmission system is a major link in the competitive energy markets, transmission operation will have reliability performance measures which must be achieved. Purchasing replacement energy through alternate transmission paths, as was done in the regulated world, is no longer an option. Transmission system managers are required to keep systems operational and will be fined if high levels of performance are not attained. The option of de-energizing systems for maintenance practices may be too costly in the deregulated world.

References

- Buchholz, F., Helicopter application in transmission system maintenance and repair, in *IEEE/CSEE Joint Conference on High-Voltage Transmission Systems in China*, October 1987.
- Caulkins, III., W., Practical applications and experiences in the installation of overhead transmission line conductors, in *IEEE/CSEE Joint Conference on High-Voltage Transmission Systems in China*, October, 1987.
- Guide to Grounding During the Installation of Overhead Transmission Line Conductors: Supplement to IEEE Guide to the Installation of Overhead Transmission Line Conductors*, IEEE 524A–1993, 1998.
- Guide to the Installation of Overhead Transmission Line Conductors*, IEEE 524–1992, 1998.
- IEEE Task Force 15.07.05.05, PE 046 PRD (04–99), Recommended Practices for Helicopter Bonding Procedures for Live Line Work.

